

A Compact Pattern Reconfigurable Antenna Utilizing Multiple Monopoles

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This presentation shows a reconfigurable antenna for optimal radiation patterns used for automotive urban scenarios. The antenna is designed to enlarge channel capacity through radiation in the best sub-channels. The information about the channel is obtained from a simulation. Presented antenna is composed of two serially fed monopoles placed on one substrate. The pattern is switched by changing the phase of the feeding signal. Thus, two patterns are obtained, whereby the first is in and opposite to the driving direction and the second is shifted by 90° in azimuth, thus orthogonal to the driving direction. The frequency of operation is chosen to be 2.45 GHz. Two prototypes of the antenna, one utilizing p-i-n diodes and one using MEMS (micro-electro-mechanical switch) as switching elements have been fabricated and measured. The antenna achieves maximum gain of about 5 dBi. Furthermore it is observed that only slight improvement is achieved if MEMS are used instead of p-i-n diodes.

Index Terms—reconfigurable, automotive, MEMS, p-i-n diode.



Jerzy Kowalewski (S'13) received the B.Sc. degree from Gdansk University of Technology, Gdansk, Poland, in 2011, and the M.Sc. degree in electrical engineering from Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany, in 2013. He is currently working toward the Dr.-Ing. (Ph.D.E.E.) degree at the Institut für Hochfrequenztechnik und Elektronik, Karlsruhe Institute of Technology (KIT). His main research topic is reconfigurable antennas with the focus on pattern reconfiguration. His further interest are antennas for communication applications and UWB antennas.

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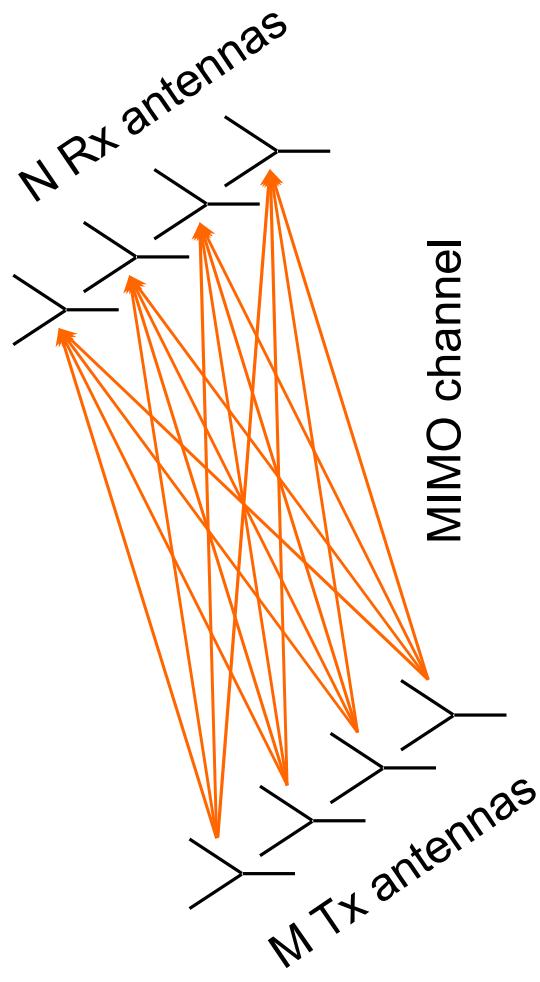


Introduction

- Multiple input, multiple output systems (MIMO) for automotive wireless communications
 - Multiple antennas with one frontend per antenna
 - Use of two effects:
 - Parallel transmission in space, multiplex (high SNR)
 - Diversity, Beamforming (low SNR)
 - Goals: increase of data rate and reduction of outage probability



Source: <http://blog.nxp.com/wp-content/uploads/2013/12/Car-Audio-Entertainment.jpg> (13.07.2015)

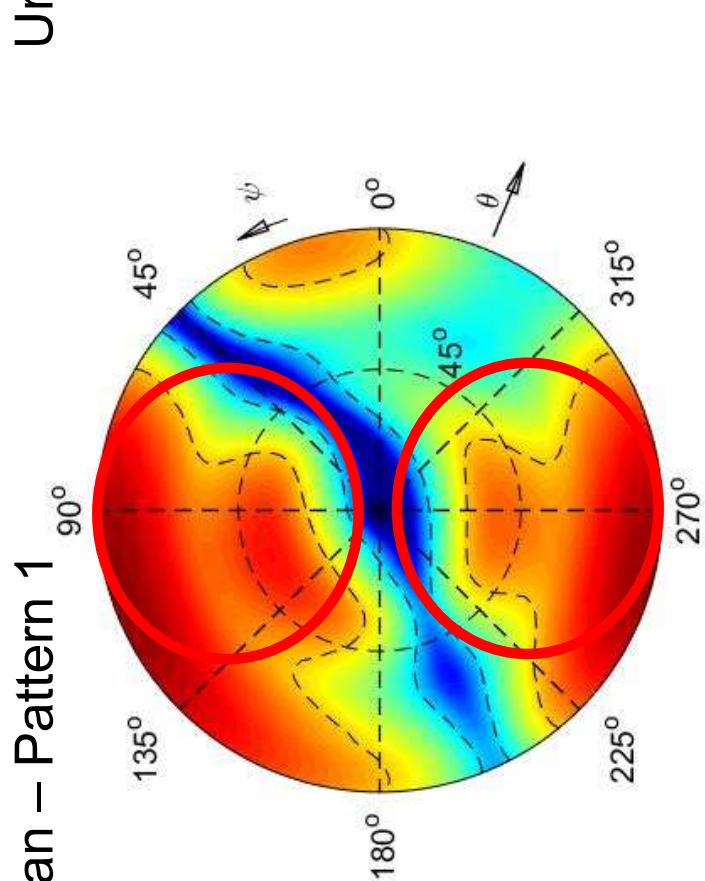
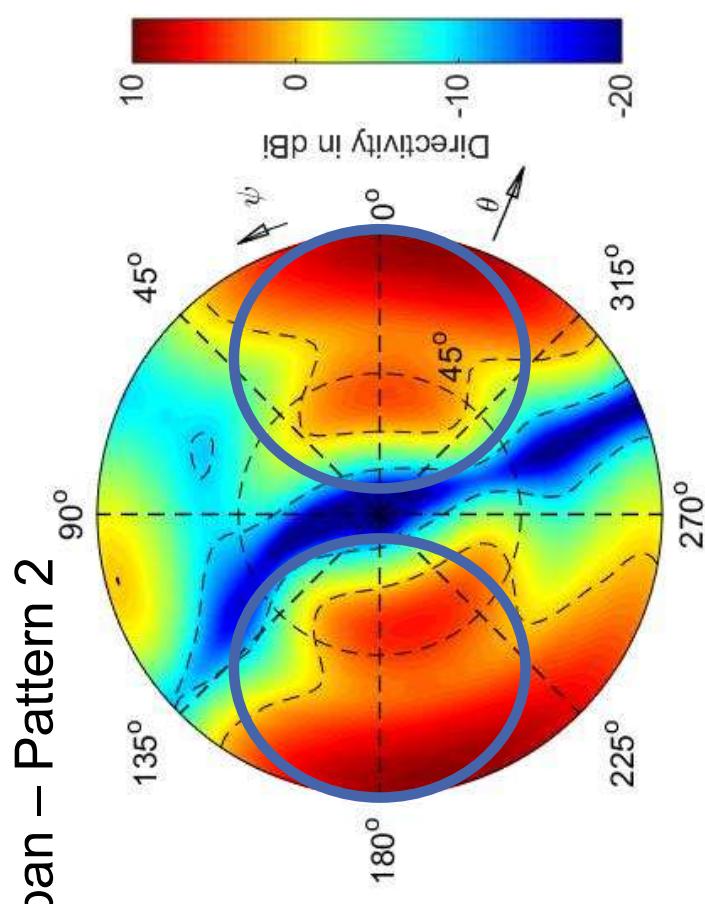


Motivation

- A MIMO system requires a full transceiver for each Tx and Rx antenna and a powerful digital signal processing.
- Most of the time the number of sub-channels used is smaller than the number of Tx/Rx antennas
- Typical MIMO systems use identical, omni-directional antennas
- **Is there a better solution for the automotive case?**
- **Reconfigurable MIMO antenna: less antennas and transceivers but beam switching for each antenna**

Synthesized Optimal Patterns

- Channel simulation and measurement prior to antenna design provides information about optimal pattern



Driving direction →

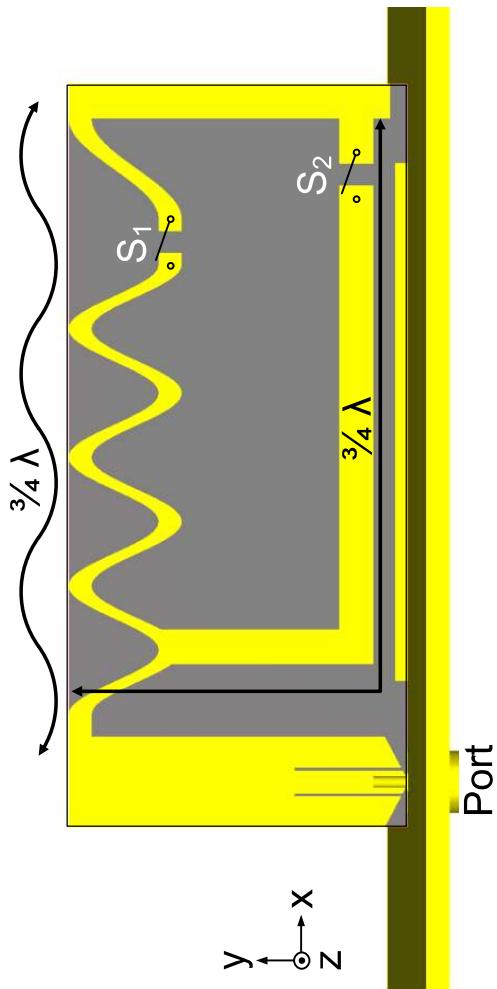
→ Target patterns to be realized by antenna designer

Antenna Principle

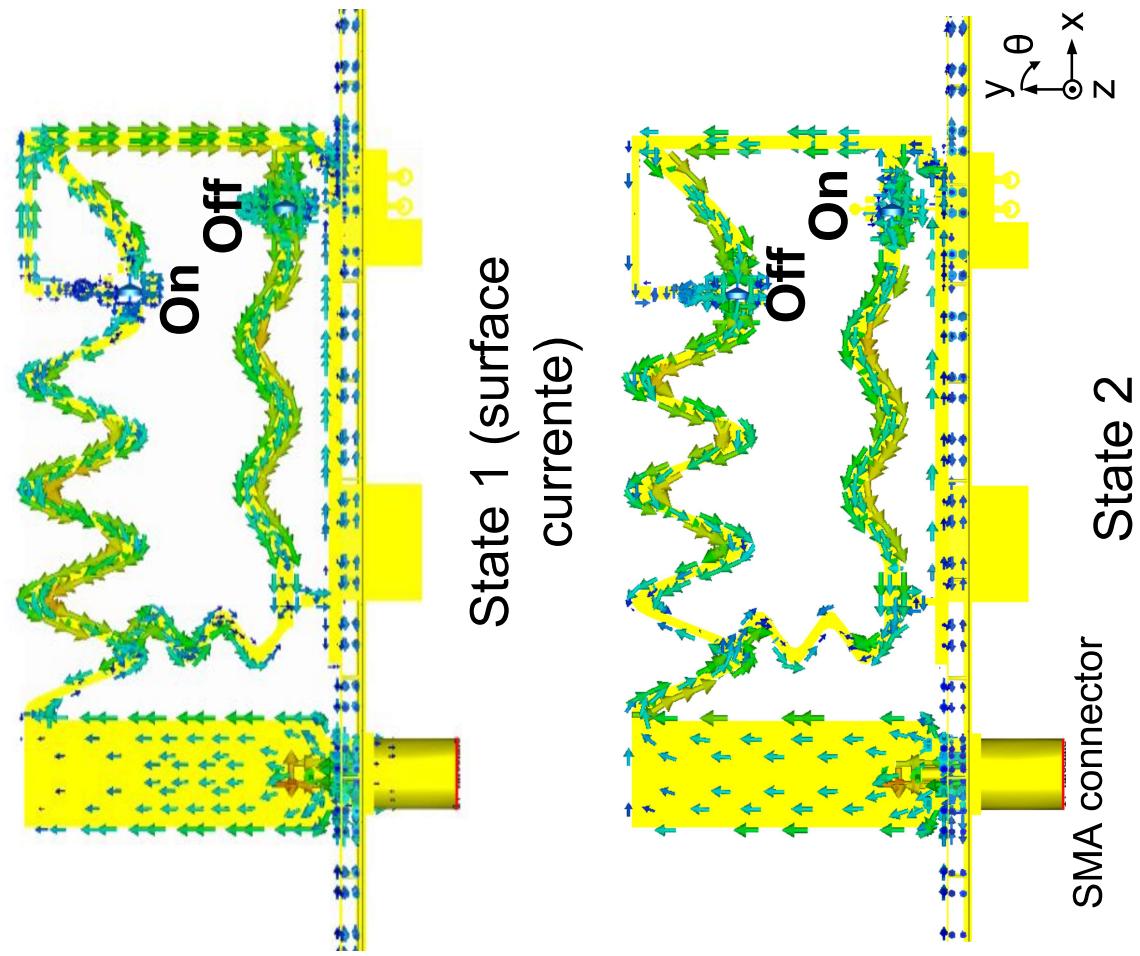
- Antenna mounted vertically on the roof ($56 \times 50 \text{ cm}^2$)
- Two monopoles separated by $\frac{\lambda}{2}$
- Series feeding
 - Two lines from left to right monopole (length $\frac{3}{4}\lambda$)
 - 0° or 180° phase shift depending on switch settings
 - Distance between junction and switches - about $\frac{\lambda}{2}$



Driving direction →

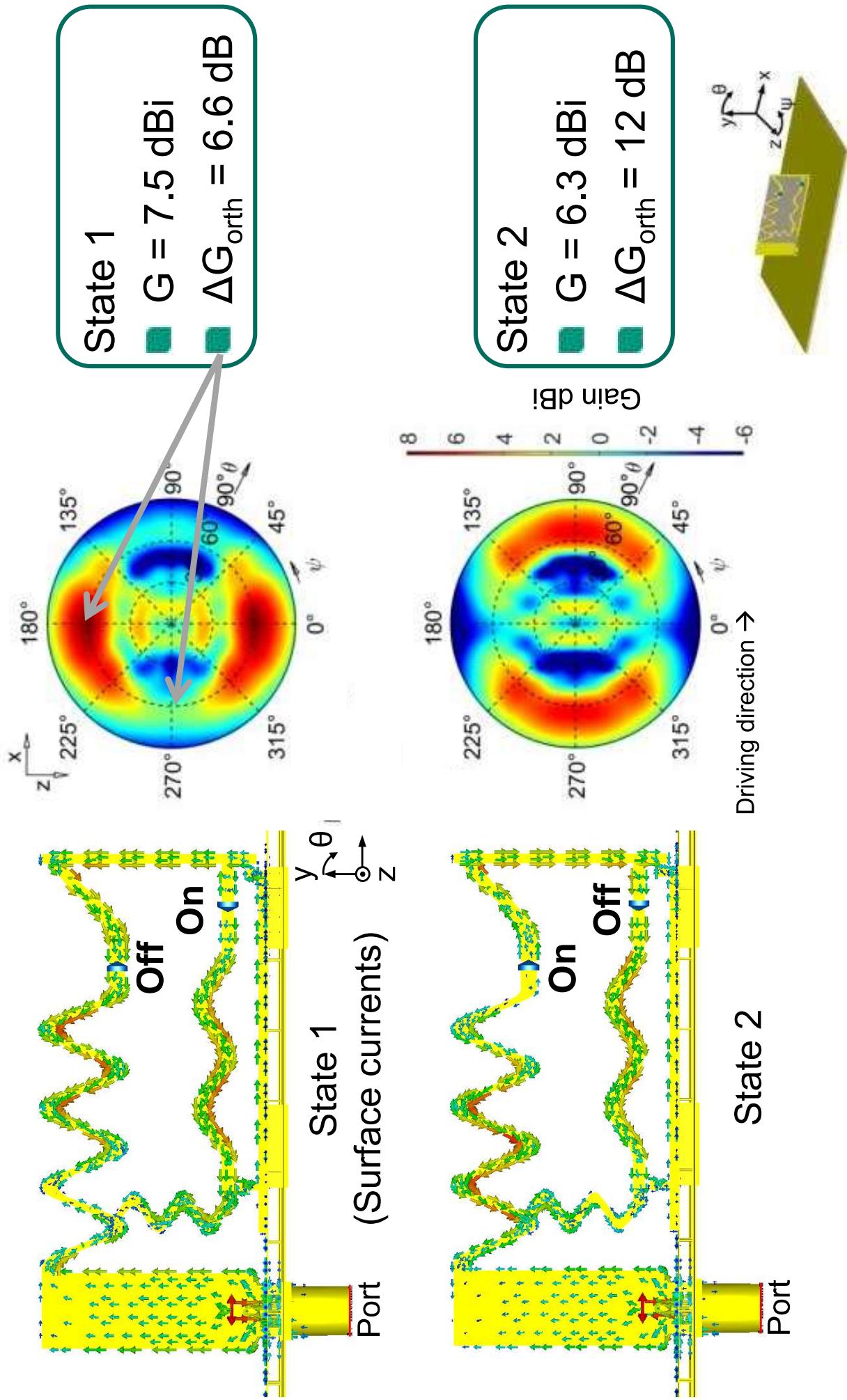


Antenna Simulation



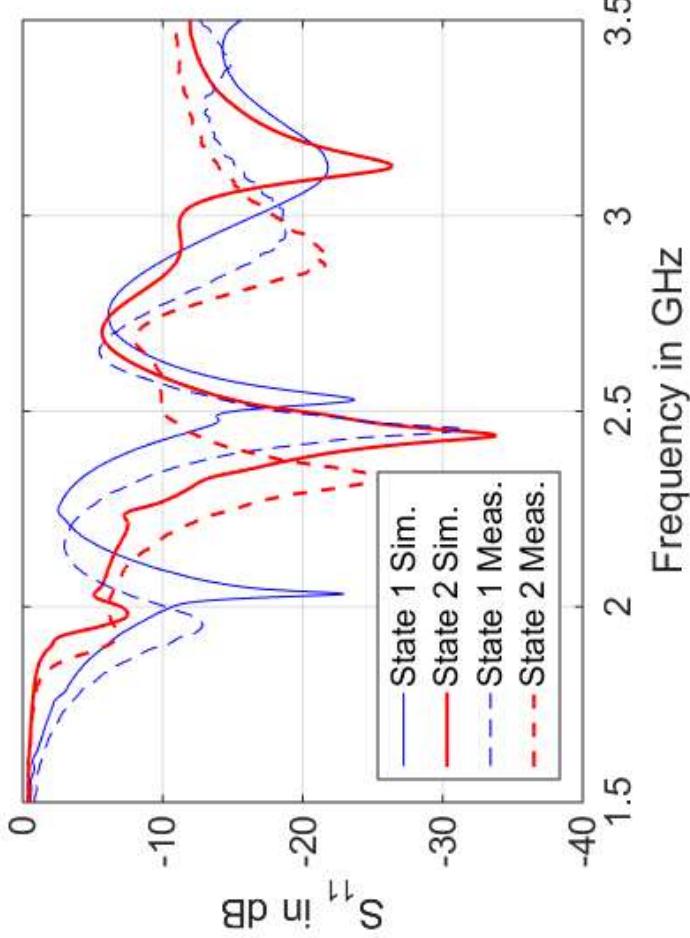
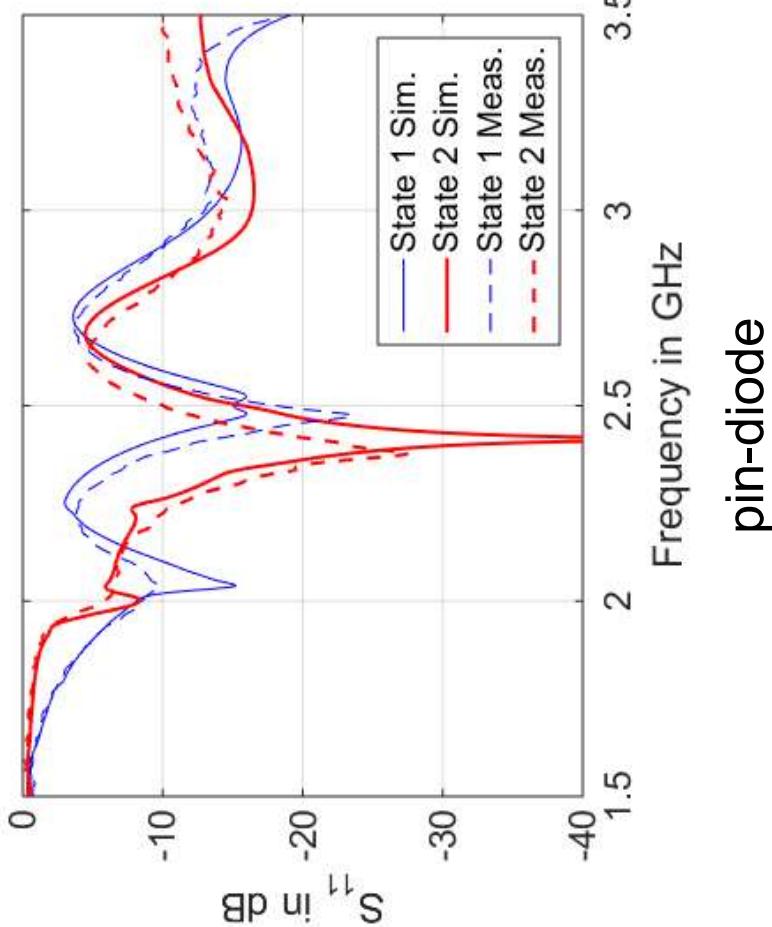
- Additional sine-waves for better phase
- RLC model for MEMS switches
- Simulation as lumped elements
- Size of antenna $60.1 \times 27.3 \text{ mm}^2$
- Smaller with MEMS model

Simulation Results (Serial Feed)



Measured Matching

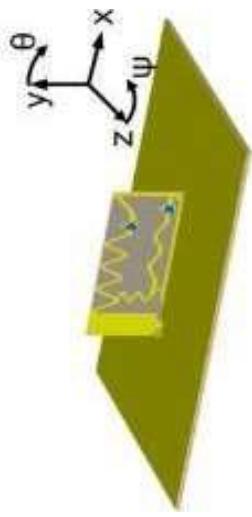
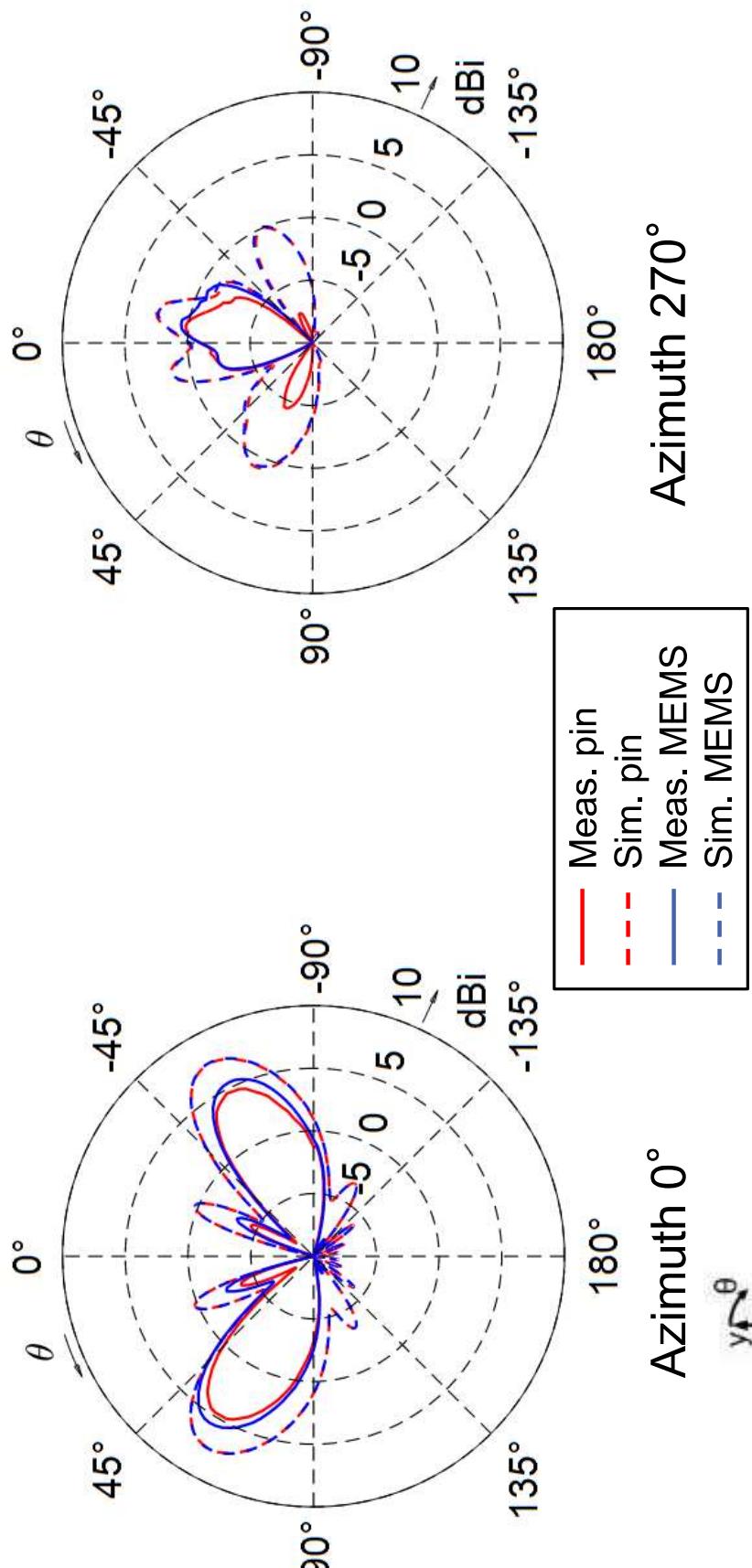
- Shift of the resonance frequency of 50 MHz and 100 MHz
 - Switch model causes bigger phase shift than expected
- 10 dB-bandwidth (6 dB-bandwidth)
 - pin: 120 MHz (240 MHz)
 - MEMS: 140 MHz (270 MHz)



pin-diode

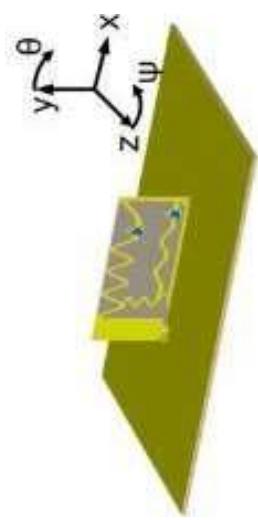
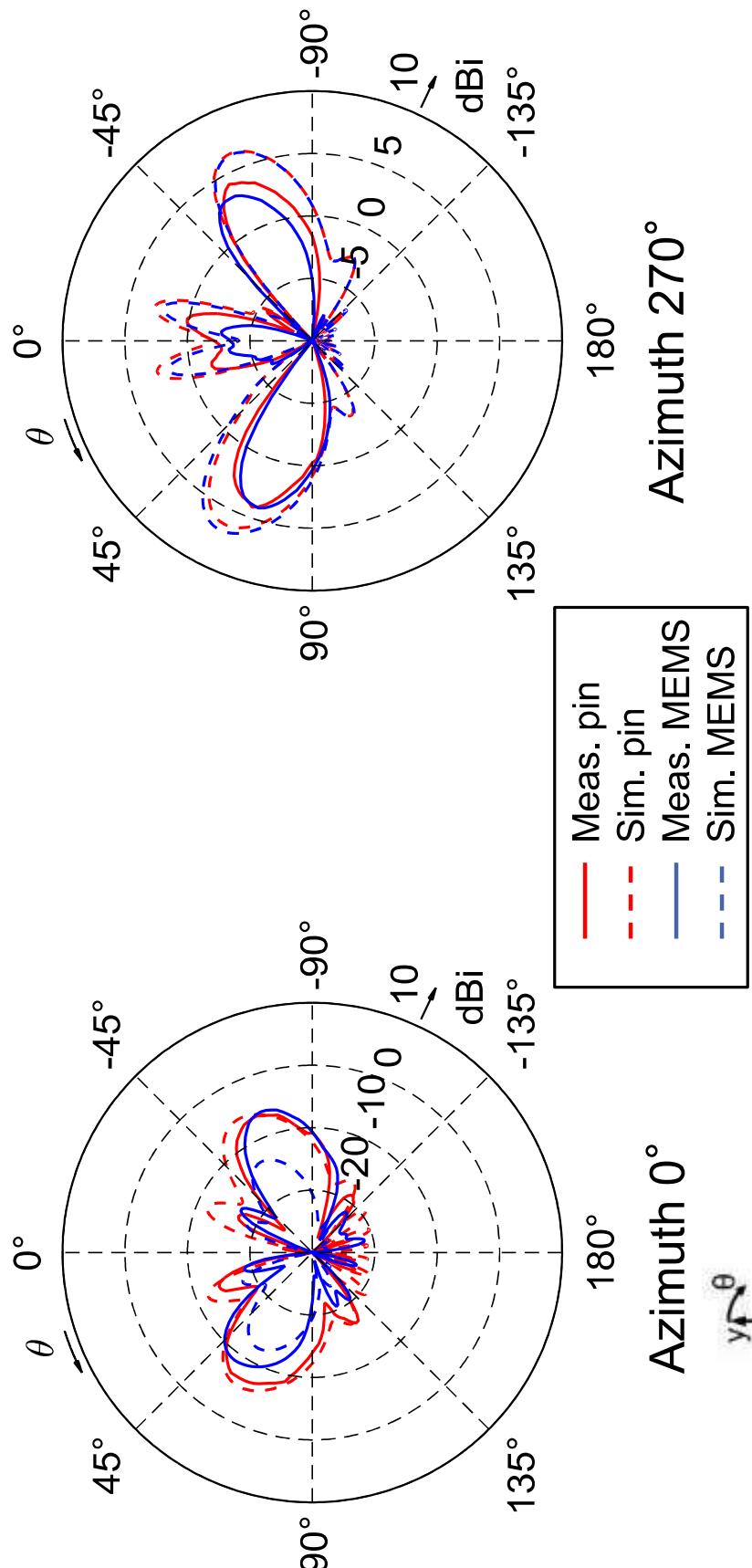
MEMS-switch

Measured Radiation Pattern for State 1



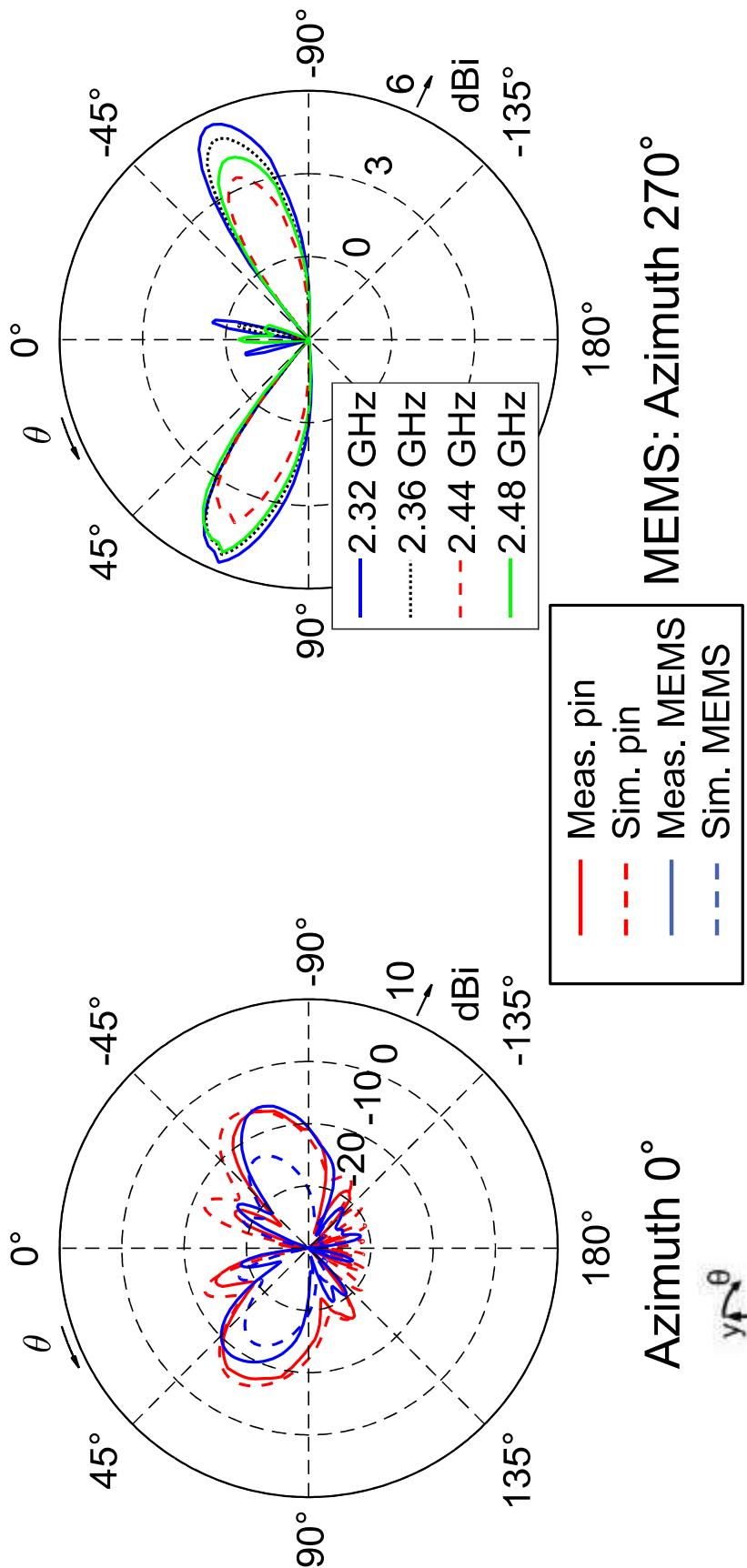
- Measurement at 2.45 GHz
- Gain 4.5 dBi and 5.5 dBi respectively
- ΔG_{orth} 9 dB bzw. 17 dB

Measured Radiation Pattern for State 2



- Measurement at 2.45 GHz
- Gain 4 dBi and 3 dBi respectively
- ΔG_{orth} 11 dB bzw. 9.5 dB

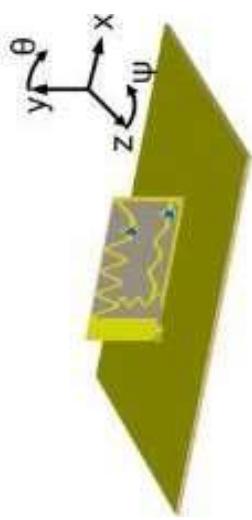
Measured Radiation Pattern for State 2



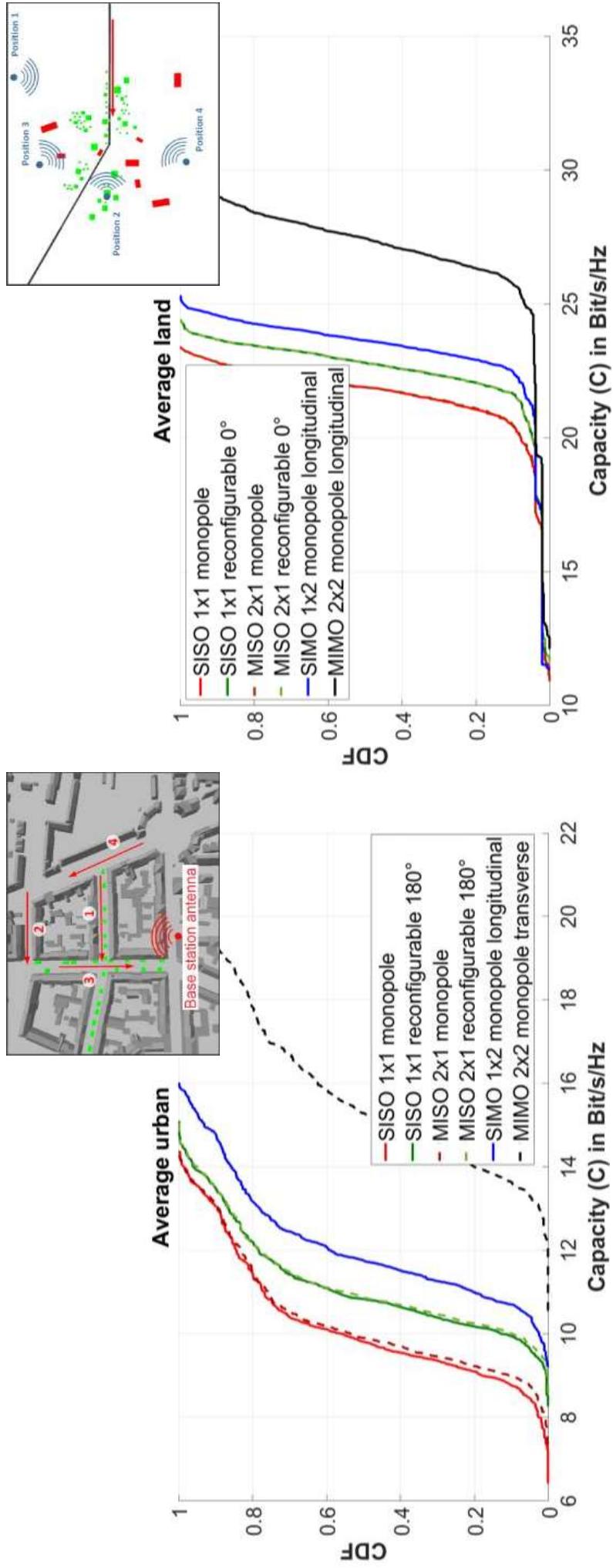
MEMS: Azimuth 270°

Meas. pin
Sim. pin
Meas. MEMS
Sim. MEMS

- Lower gain at target frequency due to frequency shift



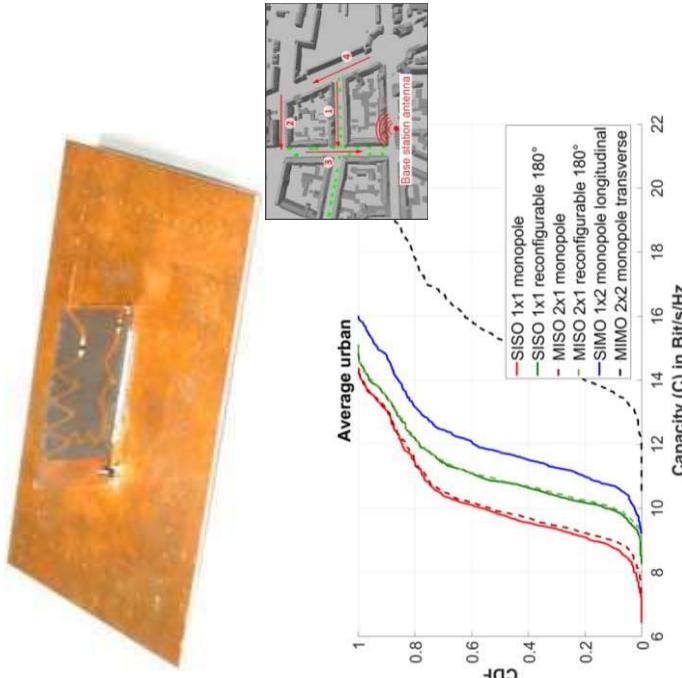
Channel capacity simulation



- An increase of data rate compared to conventional monopole antenna
- Channel capacity slightly lower compared to solution using two monopoles with separate front ends

Conclusions

- An increase of data rate compared to conventional monopole antenna
- Channel capacity slightly lower compared to solution using two monopoles with separate front ends



- Reconfigurable MIMO antennas with less antennas and transceivers but beam switching for each antenna could be a better compromise between cost and performance especially regarding the reduction of outage probability

Our other topic related work

- J. Kowalewski, T. Mahler, T. Schipper, T. Zwick, "Realization of a pattern reconfigurable antenna employing PIN diodes," in *Antennas and Propagation & USNC/URSI National Radio Science Meeting, 2015 IEEE International Symposium on*, pp. 2267-2268, Jul. 2015.
- T. Mahler, J. Kowalewski, T. Schipper, T. Zwick, "A pattern reconfigurable automotive LTE antenna employing synthesized radiation patterns," in *Microwaves for Intelligent Mobility (ICMIM), 2015 IEEE MTT-S International Conference on*, pp. 1-4, 27-29 Apr. 2015.
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- J. Kowalewski, T. Mahler, C. Heine, and T. Zwick, "Compact pattern reconfigurable LTE antenna," in *Antenna Technology: "Small Antennas, Novel EM Structures and Materials, and Applications" (iWAT), 2014 International Workshop on*, pp. 72-75, Mar. 2014.
- T. Mahler, J. Kowalewski, L. Reichardt, and T. Zwick, "Realization of a Synthesized Compact Automotive Roof-top LTE Antenna," in *Antennas and Propagation Society International Symposium 2013*, Lake Buena Vista, USA, Jul. 2013.
- J. Kowalewski, T. Mahler, L. Reichardt, and T. Zwick, "Shape Memory Alloy (SMA) Based Pattern Reconfigurable Antenna," *Antennas and Wireless Propagation Letters, IEEE*, vol. 12, pp. 1598-1601, 2013.